

VOLUME 6

DRAFT ENVIRONMENTAL IMPACT STATEMENT

GREGORY CANYON LANDFILL

San Diego County, California

APPENDIX I—GEOLOGY AND SOILS

- Peer Review of Technical Studies, Geosyntec Consultants, August 10, 2012, Revised October 12, 2012 and November 28, 2012

Memorandum

Date: 10 August 2012, Revised 12 October and 28 November 2012
To: William Miller, U.S. Army Corps of Engineers, Senior Project Manager
From: Jennifer Nevius, P.E. and Shana McCarthy
Subject: Peer Review of Technical Studies
Gregory Canyon Landfill

INTRODUCTION

This memorandum presents the results of a review of selected technical studies for the proposed Gregory Canyon Landfill (Project) in northern San Diego County, California. Gregory Canyon Limited (Applicant) has proposed the development of the Class III municipal solid waste (MSW) landfill south of State Route 76 (SR 76), approximately 3 miles east of Interstate 15. The property includes approximately 1,770 acres, with approximately 13 acres to be acquired from San Diego Gas & Electric (SDG&E) associated with the relocation of three transmission pads. Approximately 308.6 acres are proposed for overall landfill activities (e.g., stockpile areas, ancillary facilities, access road, and refuse disposal), with approximately 183 acres to be used for refuse disposal.

An Environmental Impact Report (EIR) was prepared for the Project and was certified in 2007 by the San Diego County Department of Environmental Health. Addenda to the EIR were prepared and adopted in August 2008, January 2010, and May 2010. A Joint Technical Document (JTD) for the Project was prepared by Bryan A. Stirrat and Associates (BAS), dated September 2010 and revised January 2011.

The U.S. Army Corps of Engineers, Los Angeles District (Corps) is evaluating the Applicant's Proposed Alternative in association with an Environmental Impact Statement (EIS) being prepared to satisfy the requirements of the National Environmental Policy Act (NEPA) and the U.S. Environmental Protection Agency's Section 404(b)(1) guidelines contained in 40 Code of Federal Regulations (CFR), Part 230. The Corps selected PCR Services Corporation (PCR) and its subconsultants (including Geosyntec Consultants [Geosyntec]) to prepare the EIS. The Corps is responsible for performing an independent review of the Project documentation, including various technical studies pertaining to hydrogeology, geology, and soils.

PURPOSE AND SCOPE OF SERVICES

The purpose of this review is to determine if the technical analysis is adequate to assess impacts in the EIS. Geosyntec is a consulting engineering firm specializing in landfill permitting, design, and construction. The purpose and scope of Geosyntec's professional consulting services were to provide an independent review of technical Project documentation summarized in Table 1 pertaining to hydrogeology, geology, and soils.

Table 1. Technical Studies Reviewed by Geosyntec

Technical Study	Location	Author, Reference
Geologic, Hydrogeologic, and Geotechnical Investigations Report	JTD Appendix C	GeoLogic Associates (GLA), November 2003
Supplemental Hydrogeologic Report	JTD Appendix C-1	GLA, October 2004
Technical Memorandum – Review of Issues Related to Proposed Gregory Canyon Landfill	JTD Appendix C-2	Huntley, June 2009
Monitoring and Reporting Plan	JTD Appendix G	GLA, January 2005
Water Supply Report	JTD Appendix G-1	GLA, March 2007
Workplan for Additional Groundwater Monitoring Well Installation and Wellhead Protection Area Identification	JTD Appendix G-2	GLA, July 2009
Liner Performance Evaluation, Proposed Composite Liner System	JTD Appendix H	GLA, April 2004
Phase 6 Geotechnical Investigation	EIR Appendix F	GLA, December 1998
Addendum to the Certified Final Environmental Impact Report (Text Only)	EIR Addendum	County of San Diego, December 2009
Memorandum: Response to Geosyntec Comments for the Army Corps Permit	Attachment B to this memo	GLA, July 2012
Leachate Generation Sensitivity Analyses	Attachment B to this memo	GLA, July 2012

Specifically, Geosyntec reviewed the following technical sub-areas within the referenced documents:

- Hydrogeology;
- Water supply;
- Liner system;
- Leachate generation, collection and removal;
- Seismic ground motions;
- Slope stability;
- Liquefaction;
- Rockfall and debris flow; and
- Settlement.

Geosyntec reviewed the referenced technical studies and evaluated that information with respect to current guidance, industry practice, standards, regulations including the California Code of Regulations - Title 27 (CCR Title 27), and our landfill experience. The scope of our review did not include performing detailed calculations or modeling, detailed review of existing calculations or modeling, or detailed verification of modeling parameters. However, for review of seismic ground motions and seismically-induced permanent slope displacements, it was necessary for Geosyntec to perform some level of calculation for comparison to the information reviewed.

Geosyntec also participated, along with the Applicant and GLA, in a review meeting on 18 November 2011 to discuss preliminary review comments. Documentation of the review meeting is presented in Attachment A to this memorandum. In response to this meeting, GLA prepared a memorandum responding to Geosyntec's preliminary review comments. A copy of the GLA memorandum is presented in Attachment B to this memorandum.

This memorandum represents completion of Geosyntec's work authorized by PCR on 6 September 2011, and was prepared by Jennifer Nevius, P.E. and Shana McCarthy, and reviewed by Greg Corcoran, P.E. and Veryl Wittig, P.G., C.Hg. in conformance with Geosyntec's Quality Management Program.

REVIEW FINDINGS

The findings of our review are summarized in the sections below and organized by technical area.

HYDROGEOLOGY

Geosyntec performed an independent evaluation of the hydrogeologic documents prepared for the Project by: 1) reviewing the technical documents related to groundwater migration, quality, and occurrence; 2) considering the thoroughness of the investigation activities; and 3) evaluating pertinent conclusions based on the results of those investigations. Based on our review, we concur with the investigation procedures, assumptions, and conclusions presented in the referenced GLA reports. The information reviewed pertaining to hydrogeology is consistent with or in excess of the standard of practice and is adequate for incorporation in the EIS. Specific comments are provided below regarding our review of regional and site hydrogeology, groundwater movement, and groundwater monitoring.

REGIONAL AND SITE HYDROGEOLOGY

Geosyntec concurs with GLA's interpretation of the hydrogeology and nature of the geology in the vicinity of the Project. Geosyntec concurs that the additional aquifer testing discussed in the 2009 workplan (GLA, 2009) is warranted to further evaluate the interconnectivity between the alluvial aquifer and the fractured rock aquifer. As noted by GLA (2012a), because many of the proposed wells are located within the ancillary facilities area, which will be built during the initial landfill construction phase, and will require the placement of considerable fill materials, it is proposed that the wells be constructed after the facilities area pad is complete. In this way, there is less risk of damage to the wells during the construction phase. Only proposed well GLA-18, located on a future power pole pad on the slope of Gregory Mountain, will be constructed later, after the power poles are relocated. Geosyntec concurs with the timeline for additional testing and that the evaluation of the interconnectivity performed to date is adequate to assess impacts in the EIS.

GROUNDWATER MOVEMENT

Geosyntec concurs with GLA's description of groundwater flow, namely that groundwater flow beneath the Project is northerly within the fractured rock aquifer zones. Groundwater within the alluvial aquifer located north of the proposed landfill footprint also flows northerly toward the San Luis Rey River valley.

The JTD indicates that continuous pumping of groundwater extraction wells in the fractured rock along the Point of Compliance (POC) will be operational prior to waste placement and any hypothetical release

of contaminants through the liner system. Extracted groundwater will be containerized for on-site use during construction and operation of the landfill. Granular activated carbon and reverse osmosis treatment systems will be in place prior to waste placement in the event that groundwater impacts are identified. Geosyntec concurs that the hydraulic containment zone, formed by the proposed active groundwater extraction wells and associated groundwater treatment system, is an appropriate planned corrective action measure following confirmation of a release from the landfill. The information reviewed pertaining to groundwater movement is adequate to assess impacts in the EIS.

GROUNDWATER MONITORING

Geosyntec concurs that the proposed groundwater monitoring network will provide thorough coverage of the groundwater flow system in the Project vicinity and that the proposed POC monitoring network is sufficient to detect a potential release from the Project. The Monitoring and Reporting Plan (M&RP) is sufficient to comply with CCR Title 27 to implement a Detection Monitoring Program (DMP) at the Project site. The proposed groundwater monitoring locations (including the updates from the 2009 GLA workplan) and list of analytes are adequate to detect a potential release from the Project. The information reviewed pertaining to groundwater water monitoring is adequate to assess impacts in the EIS.

WATER SUPPLY

The 2009 Addendum to the Final EIR (County of San Diego, 2009) considers a change in specification to the clay liner material, requiring the clay to be delivered to the site at moisture contents above optimum moisture content, the use of a soil sealant for dust control on unpaved roads, and an updated report of water demand. Geosyntec concurs with the conclusion of the referenced Final EIR addendum that with the combination of riparian underflow, percolating groundwater, trucked recycled water, and on-site storage, the landfill has demonstrated a likelihood of adequate water supplies being available for landfill construction and operation. The information reviewed pertaining to water supply is adequate to assess impacts in the EIS.

LINER SYSTEM

Geosyntec concurs with the proposed landfill liner performance evaluation presented in Appendix H of the JTD. As designed, the Project has a more protective liner system than the prescriptive liner system for a Class III landfill in California. The double-composite liner system on the floor of the landfill is comparable to those used in hazardous waste landfills and is substantially more protective than the single-composite liner system required as a minimum standard for MSW landfills. The information reviewed pertaining to the liner system design is adequate to assess impacts in the EIS.

LEACHATE GENERATION, COLLECTION AND REMOVAL

Geosyntec reviewed the design criteria for the Leachate Collection and Removal System (LCRS) and the available input data, methodology, and results of the leachate generation analyses referenced herein. The LCRS design and leachate generation calculations were performed initially in 1998 (GLA, 1998) and were updated in 2001 as presented in the JTD (GLA, 2003). GLA further addressed leachate generation in a response to comments memorandum (GLA, 2012a) and in a letter presenting the results of a leachate generation sensitivity analysis (GLA, 2012b); these documents are presented in Attachment B to this memorandum.

Based on the information provided, Geosyntec was not able to confirm the results of leachate generation analyses performed but was able to review the results of the analyses. In general, Geosyntec concurs with the LCRS design criteria presented in Section C.2.5.2 of the JTD. The overall leachate system design, incorporating a blanket LCRS layer with a system of dendritic pipes, is consistent with the state of the practice in California and semi-arid environments. Further, Geosyntec concurs that the proposed LCRS provides the capacity to collect leachate anticipated to be generated from the facility over the life of the landfill while maintaining a maximum head of less than 12 inches as required by state and federal regulations. In our opinion, the analyses conducted to date are adequate to assess impacts in the EIS.

Final design of the landfill cells (typically performed prior to constructing each cell) should include updated analyses that incorporate specific LCRS gradients and pipe spacing for each cell and initial operational conditions. As indicated by GLA (2012a), financial assurance for post-closure maintenance should include costs for collection and handling of leachate.

SEISMIC GROUND MOTIONS

Geosyntec's review evaluated the design seismic ground motion parameters developed for the Project as presented in the JTD (BAS, 2011), the Phase 6 Geotechnical Investigation (GLA, 1998), and the response to comments memo (GLA, 2012a).

In accordance with the CCR Title 27 requirements for Class III MSW landfills, the design earthquake for the Project is the Maximum Probable Earthquake (MPE). However, to provide an additional margin of safety, and in accordance with CCR Title 27 Section 21750(f)(5)(C)(7), the Project was designed to resist the Maximum Credible Earthquake (MCE), the more stringent standard of seismic design mandated for designated waste and hazardous waste landfills in California.

Geosyntec performed an independent evaluation of the MCE design ground motions for the Project site based on the following information:

- Approximate geometric center of the landfill with latitude and longitude of 33.3382, -117.1045 estimated using Google Earth;
- MCE for the site is a moment magnitude (M_w) of 7.1 on the Julian Segment of the Elsinore Fault (same as in the JTD);
- Site-to-source distance of 5 miles (approximately 10% shorter than JTD; evaluated from the United States Geological Survey digital database referenced in the JTD);
- Site conditions: free-field; "weak rock;" mean value of five attenuation relationships for acceleration, median value for significant duration of strong ground shaking;
- Acceleration attenuation model from the 2008 Next Generation Attenuation (NGA) attenuation relationships (Abrahamson et al., 2008); and
- Significant duration model from Kempton and Stewart (2006).

For the site conditions outlined above, Geosyntec estimated a Peak Horizontal Ground Acceleration (PHGA) of 0.28 g and significant duration of strong ground shaking of 17 seconds. The PHGA calculated by Geosyntec is approximately 20% lower than reported in the JTD. This result is expected,

as PHGA calculated by NGA models is typically lower than calculated using the 1997 attenuation models. It is our opinion that the PHGA value of 0.40 g reported by BAS (2011) is conservative. We note that, based on recent advances in attenuation relationships and seismic modeling, the BAS (2011) seismic hazard analysis supersedes the GLA (1998a) seismic hazard analyses.

During final design (typically performed after environmental review and prior to constructing each cell), the seismic hazard evaluation performed by BAS (2011) could be updated to include NGA attenuation models, revised site-to-source distance, and discussion of the site conditions for which the analysis was performed. This seismic hazard evaluation should document the design acceleration response spectra and significant duration of strong ground shaking, as these parameters are required for development of design ground motions and simplified seismic deformation analysis. As such, additional analyses may be desired by the Applicant as part of final design; however, the analyses presented in the JTD (BAS, 2011) are adequate to assess impacts in the EIS.

SLOPE STABILITY

Geosyntec's review evaluated the slope stability analyses performed for the Project as presented in the JTD, the Phase 6 Geotechnical Investigation (GLA, 1998a), and the response to comments memorandum (GLA, 2012a). The referenced slope stability analyses included: two-dimensional (2-D) stability analyses for cut slopes, stockpile slopes, refuse slopes, and final cover slopes; and three-dimensional (3-D) stability analyses for refuse slopes. In addition, seismic deformation analyses were performed for refuse slopes and final cover slopes. In our opinion, the referenced stability analyses performed to date are adequate to assess impacts in the EIS.

MATERIAL PROPERTIES

Based on our experience, the material properties assumed for the stability analyses are reasonable to assess impacts in the EIS.

2-D STATIC STABILITY ANALYSES

CUT SLOPES AND STOCKPILE SLOPES

Geosyntec evaluated the static stability of cut slopes by reviewing the methodology outlined in Appendix C of the JTD, including stereographic pole-plots and rose diagrams for fractures and the proposed excavation plans. Based on the available data reviewed, the GLA approach appears consistent with the standard of practice for stability and kinematic analyses of the rock mass. Geosyntec concurs with GLA's conclusion that block-and wedge failure is infeasible based on the measured structural orientations of discontinuities.

Geosyntec evaluated the stockpile stability by reviewing the maximum height and slope inclination, and the assumed material properties presented in the JTD. Based on the analyses reviewed, the stockpile stability evaluation utilizing the computer program SLOPE/W appears consistent with the standard of practice for stockpile stability.

REFUSE SLOPES

Geosyntec evaluated the static stability of the refuse prism by reviewing the selected cross-sectional geometry, the assumed material properties, and the analysis methodology presented in the JTD.

Geosyntec reviewed the geometry of the master excavation plan and the proposed final grading plan to evaluate the selected refuse slope cross section analyzed by GLA. The selected cross section is generally aligned in a northwest-southeast orientation through the approximate center of the landfill. The section is perpendicular to the majority of the excavation floor grades, representing the steepest section of the landfill floor. It is likely that this section represents the most critical cross section for refuse slope stability for the fully developed landfill. The refuse slope stability analysis utilized the computer program SLOPE/W, which is consistent with the state of practice for stability analyses.

Based on the results of our review, the geometry and methodology utilized by GLA in the 2-D static stability analysis for cut slopes, stockpile slopes, and refuse slopes are adequate to assess impacts in the EIS. Final design (typically performed after environmental review and prior to constructing each cell) should include updated analysis that incorporates specific grades and liner material properties proposed for each cell, as well as interim stability conditions.

FINAL COVER SLOPES

Geosyntec reviewed the stability analyses performed for the final cover materials as presented in Appendix C of the JTD and in the response to comments memorandum (GLA, 2012a). We concur that the results of the final cover slope stability analyses presented for the static and seepage conditions exceed the minimum required factor of safety, and are adequate to assess impacts in the EIS. Final design (typically performed after environmental review and prior to constructing each cell) should evaluate grades and liner/cover soil interface material properties specific to the Project and their effect on final cover stability.

2-D SEISMIC STABILITY ANALYSES

REFUSE SLOPES

To evaluate Cross Section A-A' for seismic refuse slope stability, Geosyntec reviewed the SLOPE/W model described above, the reported pseudostatic coefficient and yield acceleration utilized by GLA. Because the pseudostatic factor of safety was less than 1.5, CCR Title 27 requires a more detailed seismic deformation analysis.

Geosyntec also reviewed the GLA calculations for seismically induced permanent displacement along the base liner. Our review consisted of repeating the seismic deformation analysis presented in the JTD, but with an updated seismic deformation model and MCE seismic hazard parameters evaluated as a part of this review. In particular, Geosyntec utilized the Bray and Travarasrou (2007) seismic deformation procedure, average shear wave velocity profile of refuse presented by Matasovic and Kavazanjian (1998), and seismic hazard parameters including: MCE; PHGA = 0.28 g; spectral acceleration at a degraded period = 0.12 g; and yield acceleration = 0.11 g. The results indicate that seismically induced permanent displacement along the base liner is low (less than 1 inch). Geosyntec's assessment is consistent with the assessment presented in the JTD, and meets the standard of practice stability criterion of 6 inches of maximum calculated permanent seismic displacement.

Modeling the currently calculated yield acceleration as representative, the calculated permanent seismic displacements due to the MCE are likely within the limits of currently acceptable values for seismic design of MSW landfills in California (less than 6 inches of maximum calculated permanent seismic

displacement). Based on the results of our review, the analyses presented for seismic stability of the refuse slopes are adequate to assess impacts in the EIS.

FINAL COVER SLOPES

Geosyntec also reviewed the GLA calculations for seismically induced permanent displacement of the final cover. Our review consisted of repeating the GLA (2003) seismic deformation analysis, the results of which were presented in the JTD, but with updated MCE seismic hazard parameters evaluated as a part of this review. In particular, Geosyntec employed the Makdisi and Seed (1978) seismic deformation procedure (same as GLA), and seismic hazard parameters including a MCE M_w of 7.1 and bedrock PHGA of 0.28 g. We further evaluated the effect of waste fill on bedrock PHGA (i.e., the amplification of waste fill) and evaluated the PHGA at the landfill cover level as 0.6 g. This evaluation is based upon the U.S. EPA procedure outlined in Richardson et al. (1995) and the Harder (1991) chart for amplification of bedrock motions in earth dams, and is conservative. The calculated yield acceleration of composite landfill cover, as evaluated by Geosyntec, is 0.11 g. The calculation brief prepared by GLA (2012a) estimates a yield acceleration of 0.15 g.

The results of our seismic displacement evaluation indicate that seismically induced permanent displacement of the final cover is on the order of 36 inches. Although Geosyntec estimated a larger displacement, our overall conclusion is consistent with the assessment presented in the JTD. Assuming that the currently calculated yield acceleration is representative, calculated permanent seismic displacements from the MCE for the final cover slopes are likely within the limits of currently acceptable values for seismic design of MSW landfills in California (less than 36 inches of maximum calculated permanent seismic displacement). Future analysis (typically performed after environmental review and prior to constructing each cell) should confirm or update the estimated permanent seismic displacements for the final cover. Based on the results of our review, the analyses presented for seismic stability of the final cover slopes are adequate to assess impacts in the EIS.

3-D STABILITY ANALYSES

3-D stability of the refuse fill was performed using the computer program CLARA, and was presented in Appendix 3 of the Phase 6 Geotechnical Investigation (GLA, 1998a). Geosyntec's review of the CLARA output identified some apparent inconsistencies with the 2-D stability analysis presented in the JTD, and in our comments, questioned if additional 3-D stability analyses had been performed. The response to comments memorandum (GLA, 2012a) indicates that the 3-D slope stability analysis was updated by a 2-D slope stability program (SLOPE/W) during additional analysis performed in May 2003 (GLA, 2003), and supersedes the previous 3-D slope stability analysis. However, based on the relatively narrow canyon with side slopes lined with material of low frictional resistance, we recommend that 3-D effects be considered during final design (typically performed after environmental review and prior to constructing each cell) of the Project.

LIQUEFACTION

A detailed discussion of the GLA liquefaction susceptibility evaluation was presented in the Phase 6 Geotechnical report for the Project (GLA, 1998a). This evaluation considered data from four borings drilled in the alluvial wedge in the area of the Project ancillary facilities at the mouth of Gregory Canyon,

as indicated on Figure 1-2 of Appendix C of the JTD. Planned grading operations will remove loose soils from the landfill footprint; therefore, liquefaction evaluation within the landfill footprint is not warranted.

The evaluation data included seismic ground motions, design earthquake magnitude, field Standard Penetration Test (SPT) blowcounts, and geotechnical laboratory test data. The ground motion used for the GLA analysis was 0.31 g for alluvial materials, adapted from the PHGA of 0.40 g for bedrock materials. Although no calculation for the ground motion reduction was indicated in the documentation reviewed, as outlined above, the design bedrock ground motion estimated by Geosyntec was 0.28 g, approximately 10% lower than the ground motions used in the liquefaction analysis. The lowest factor of safety calculated against liquefaction by GLA was 1.3, compared to published standard of practice guidelines between 1.25 and 1.5 for liquefaction hazards as reported by SCEC (1999).

We have reviewed the analysis input data and methodology and concur with the overall results of the GLA liquefaction evaluation, specifically that for existing conditions, the liquefaction susceptibility of the alluvial wedge at Gregory Canyon is low, and not a significant impact to the Project. The referenced results of the liquefaction evaluations are adequate to assess impacts in the EIS.

ROCKFALL AND DEBRIS FLOW

The most conservative GLA rockfall evaluation scenario estimated a maximum encroachment of a bouncing or rolling rock fragment onto the landfill of about 300 to 360 feet (GLA, 2003). GLA recommended “catching walls” or other diversion structures near the edge of the landfill to mitigate the risk of rock fragments rolling onto the landfill (GLA, 2003). The conclusions reached through the analysis of this profile are applied generally to the eastern slope of the Project site. We have reviewed the GLA rockfall evaluation and concur with the overall results; specifically, that rockfall hazard is not a significant impact to the project. The referenced results of the rockfall evaluations are adequate to assess impacts in the EIS.

We have reviewed the analysis input data and methodology and concur with the overall results of the GLA debris flow evaluation, namely that, for existing conditions, debris flows are not a significant impact to the Project considering the planned retention structures and vegetation management. The referenced results of the debris flow evaluations are adequate to assess impacts in the EIS.

SETTLEMENT

REFUSE SETTLEMENT

We reviewed the refuse settlement analysis input data and methodology presented in Appendix C of the JTD. We note that the summary in Section E.1.4.1 of the JTD (BAS, 2011) is inconsistent with the settlement analysis in Appendix C of the JTD (GLA, 2003), citing a 30% rather than a 25% total refuse settlement value. However, Geosyntec concurs with the overall methodology and order of magnitude of the GLA refuse settlement estimate, and reaches the same conclusion that refuse settlement is not a significant impact to the Project with routine maintenance of the landfill surface grades. The referenced results of the refuse settlement evaluations are adequate to assess impacts in the EIS.

FOUNDATION SETTLEMENT

An analysis considering the differential settlement between the bedrock and the engineered fill embankments that are planned as part of the landfill construction was not detailed in the JTD. The response to comments memorandum (GLA, 2012a) indicates that an evaluation was performed addressing the potential for differential settlement at the interface between the compacted fill materials and the weathered granitic materials at the new landfill subgrade. The evaluation concludes that considering the relatively gentle site grades and the relatively granular composition of the proposed fill soils, the anticipated differential settlement between the different foundation materials is expected to be well within the elongation characteristics of the proposed membrane liner materials. The referenced results of the foundation settlement evaluations are adequate to assess impacts in the EIS.

CONCLUSIONS

As summarized in this memorandum, Geosyntec performed a review of the referenced selected technical studies pertaining to hydrogeology, geology, and soils on behalf of the Corps. In general, Geosyntec concurs with the approach, methodology, and overall results of the reviewed technical evaluations presented in the referenced documents. We consider the material in these technical studies adequate to assess impacts in the EIS. We have noted the following specific issues for further consideration during final design of the Project:

- Additional evaluation of interconnectivity between the alluvial and the fractured rock aquifers;
- Confirmation or update of leachate generation analyses that incorporate specific LCRS gradients and pipe spacing for each cell and initial operational conditions;
- Confirmation or update of slope stability analysis for waste slopes and final cover slopes, utilizing specific properties for proposed materials, and for temporary, long-term static, seismic, or seepage design conditions as appropriate; and
- Confirmation or update of estimates of seismically-induced deformation for the refuse and cover slopes.

These considerations are either currently planned for the Project (e.g., aquifer interconnectivity per GLA [2009]), or are performed consistent with the standard of practice for landfill projects in California. CCR Title 27 Section 21760(a)(1) requires that a design report be approved by the State Water Resources Control Board (locally the Regional Water Quality Control Board [RWQCB]) that includes detailed preliminary and (later, after construction) as-built plans, specifications, and descriptions for all liners and other containment structures, LCRS components, leak detection system components, precipitation and drainage control facilities, and interim covers installed or to be installed or used.

CLOSURE

We appreciate the opportunity to assist you with this important project. Should you have any questions regarding the contents of this memorandum, please contact us.

Attachments

Attachment A – Meeting Documentation, Peer Review of Technical Studies

Attachment B – GLA Response to Geosyntec Comments Memorandum

REFERENCES

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ATTACHMENT A

Meeting Documentation, Peer Review of Technical Studies

Memorandum

Date: 14 December 2011, Revised 12 April and 28 November 2012
To: William Miller, U.S. Army Corps of Engineers, Senior Project Manager
From: Jennifer Nevius, P.E.
Subject: Meeting Documentation
Peer Review of Technical Studies
Gregory Canyon Landfill

INTRODUCTION AND BACKGROUND

The purpose of this memorandum is to document a meeting with Gregory Canyon Ltd. (Applicant) and the Applicant's Consultants (including Geo-Logic Associates [GLA]) to discuss third party review of selected technical studies for the proposed Gregory Canyon Landfill (Project) in northern San Diego County, California.

The Applicant has proposed the development of the Gregory Canyon Landfill south of State Route 76 (SR 76), approximately 3 miles east of Interstate 15. The proposed landfill is adjacent to the San Luis Rey River and the western slope of Gregory Mountain.

The U.S. Army Corps of Engineers, Los Angeles District (Corps) is evaluating the Applicant's Preferred Alternative in association with an Environmental Impact Statement (EIS) being prepared to satisfy the requirements of the National Environmental Policy Act (NEPA) and the U.S. Environmental Protection Agency's Section 404(b)(1) guidelines contained in the 40 Code of Federal Regulations, Part 230. The Corps selected PCR and its subconsultants (including Geosyntec Consultants [Geosyntec]) to prepare the EIS. The Corps is responsible for performing an independent review of the Project documentation, including various technical studies, including geology and soils, hydrogeology, and surface hydrology. The purpose of this review is to determine if the technical analysis is adequate for use in the EIS.

Geosyntec has reviewed selected Project technical studies, primarily authored by GLA pertaining to hydrogeology and soils as they pertain to landfill design. Geosyntec provided preliminary review comments in a draft memorandum to PCR, identifying issues for additional clarification or consideration. Discussion with involved parties for this Project indicated that it would be beneficial to meet and discuss the issues identified.

MEETING SUMMARY

The intent of this memorandum is to document a meeting held between 1500 and 1600 hours on 18 November 2011 to discuss the issues identified by Geosyntec during our peer review of selected technical studies for the project. Table 1 below summarizes the meeting participants and involved parties.

Table 1. Review Meeting Participants and Involved Parties

Individual	Affiliation	Title, Project Role	Attended Meeting
Bill Miller	Corps	Senior Project Manager - Corps	No
Luci Hise	PCR	Associate Principal, Project Manager, Consultant to Corps	No
Jim Simmons	Gregory Canyon Ltd.	Project Manager - Applicant	Yes
William Hutton, Esq.	Law Offices of E. William Hutton	Legal Counsel to Applicant	Yes
Richard Felago	The Felago Group, LLC	President, Management Advisor to Applicant	Yes
Bill Magdytch	Bill Magdych Associates	Principal, Consultant to Applicant	Yes
Jennifer Nevius, PE, GE	Geosyntec	Project Engineer, Project Manager, Consultant to PCR	Yes
Greg Corcoran, PE	Geosyntec	Principal, Senior Review, Consultant to PCR	Yes
Sarah Battelle, PG, CHg	GLA	Vice President, Project Manager, Consultant to Applicant	Yes
Joseph Franzone, PE, GE	GLA	Supervising Geotechnical Engineer, Consultant to Applicant	Yes
William Lopez, RG, CEG, CHg	GLA	Senior Geologist, Consultant to Applicant	Yes

The meeting agenda, which summarizes the issues discussed is presented below.

1. Clarification of the timing of installation and testing of wells proposed in the 2009 workplan to further evaluate the interconnectivity between the alluvial aquifer and the fractured rock aquifer.
2. Review of input parameters and results of leachate generation modeling, including:
 - o Leaf area index;
 - o The evaporation zone depth for the anticipated soil type and vegetation conditions;
 - o Modeling of leachate generation during initial cell operation in addition to the active period;
 - o Impact of liner system modeled; and
 - o Predicted trends in leachate generation rates over time.
3. Review of potential effect of advances in the state of the practice on seismic design (e.g. Next Generation Attenuation models).
4. Review of material parameters utilized for the final cover/geomembrane interface used for the slope stability and seismic deformation analyses. Was a seepage condition evaluated?
5. Review of material properties and design configuration utilized in 3-D slope stability analyses.
6. Clarification if an evaluation was performed to address the potential for differential settlement between foundation material types.

The conclusion of the meeting was that GLA will prepare documentation addressing the issues identified, either by clarification or providing supplemental information. We understand that this documentation will be provided to the Corps by the Applicant.

ATTACHMENT B

GLA Response to Geosyntec Comments Memorandum

MEMORANDUM

TO: William Miller, U.S. Army Corps of Engineers, Senior Project Manager

FROM: Sarah Battelle, Geo-Logic Associates

DATE: May 25, 2012

REVISED: July 2, 2012

RE: **RESPONSE TO GEOSYNTEC COMMENTS FOR THE ARMY CORPS PERMIT
GREGORY CANYON LANDFILL
SAN DIEGO COUNTY, CALIFORNIA**

In response to the comments from GeoSyntec Consultants as presented in a meeting at our office in November 2011, regarding review of the geotechnical information to date (for the Army Corps permit) for the Gregory Canyon Landfill, Geo-Logic Associates (GLA) provides our responses (in the order that the comments were presented), as follows.

Comment No. 1: Clarification of the timing of installation and testing of wells proposed in the 2009 work plan to further evaluate the interconnectivity between the alluvial aquifer and the fractured rock aquifer.

Response to Comment No. 1: Because many of the proposed wells are to be located within the facilities area, which will be built during early landfill construction, and will require the placement of considerable fill materials, it is proposed that the wells be constructed after the facilities area pad is complete. In this way, there is less risk of damage to the wells during the construction phase. Only well GLA-18, located on a future power pole pad on the slope of Gregory Mountain, will be constructed later, after the power poles are relocated.

Comment No. 2: Review of input parameters and results of leachate generation HELP modeling, including:

- *Leaf area index;*
- *The evaporation zone depth for the anticipated soil type and vegetation conditions;*
- *Modeling of leachate generation during initial cell operation in addition to the active period;*
- *Impact of liner system modeled; and*
- *Predicted trends in leachate generation rates over time.*

Response to Comment No. 2: Because considerable time has elapsed since the original leachate generation modeling was completed and the U.S. Army Corps of Engineers has developed a more recent version (version 3.07) of its computer program HELP (Hydrologic Evaluation of

Landfill Performance), GLA has performed a simplified (5-year incremental) leachate generation “baseline” reconstruction of the previously completed leachate generation analysis (GLA, 1998; and addendum GLA, 2001), which had been completed using the most current version of the HELP available at that time (version 3.06), to support the original model and establish that the original model results used to design the leachate collection and recovery system remain applicable for landfill design purposes. In addition, sensitivity analyses were performed for the various input parameters to demonstrate their effects on the leachate generation model.

Based on the “baseline” leachate generation analysis and parameter sensitivity analyses performed using the most current version of HELP (version 3.07) for the Gregory Canyon Landfill, it is concluded that the original (1998) modeling results (performed using earlier version 3.06) are reasonable and appropriate for the site design. The updated “baseline” leachate generation analyses were compared to actual leachate volumes measured at the Miramar Landfill, which is a similar sized, lined landfill (180 acres), and the 150-acre Sycamore Landfill, both of which are located in San Diego County and which experience similar weather patterns to the GCLF. The updated results compare favorably with the 1998 modeling, and the results of the sensitivity analysis suggest that the input parameters selected are appropriate. The report summarizing the most recent leachate generation sensitivity analyses is included as an attachment to this memorandum. Responses to Comment No. 2 follow:

Review the Leaf Area Index. Why was LAI = 1 used?

Leaf area index (LAI) is defined in the HELP model (Schroeder et al., 1994) as the dimensionless ratio of the leaf area of actively transpiring vegetation to the nominal surface area of the land on which the vegetation is growing. The maximum LAI for bare ground is zero. For a poor stand of grass the LAI could approach 1.0; for a fair stand of grass, 2.0; for a good stand of grass, 3.5; and for an excellent stand of grass, 5.0. The interim cover of most landfills would tend to have at best a fair stand of grass and often only a poor stand of grass because landfills are not designed as ideal support systems for vegetative growth. Use of a LAI of 1 to represent a poor stand of grass development on the landfill was considered reasonable because the landfill operations will include placement of interim cover and re-vegetation of areas of the landfill that will be inactive for more than 180 days resulting in a higher grass density to minimize soil erosion.

Review the evaporation zone depth for the anticipated soil type and vegetation conditions. Why was a depth of 32” used?

Rain water that does not run off the landfill may migrate through the cover or be pulled out of the soil column via evaporation and/or plant transpiration. The potential for moisture to be pulled upward from soil is a function of soil type, presence of vegetative cover characteristics, temperature, and solar radiation. The depth to which evaporation of water can occur can greatly exceed the depth to which plant roots extend and can occur even if there is no vegetation at all. The 1998 and updated leachate generation models use an evaporative zone depth (EZD) of 32 inches based on the suggested range of values in the HELP model documentation, which is an “intermediate” value consistent with clayey and silty soils and that

will be used at the GCLF for daily and intermediate soil cover. Use of evaporative zone indices greater than or less than 32 inches result in over- or under-estimation of leachate volumes when compared to actual measured volumes from the active, 180-acre Miramar Landfill, or 150-acre Sycamore Landfill, both of which are located within San Diego.

Review modeling of leachate generation during initial cell operation in addition to the active period. Was refuse placement modeled differently? If so. How?

HELP is an “annual” model, in which any changes are introduced abruptly at the start of the year. In the original (1998) work the refuse was assumed to have been placed instantaneously at the start of the year, and remained “exposed” throughout the active life of the cell. This interpretation allows for more leachate to be generated than would actually be expected under standard landfill operations, where daily and interim cover soils are placed over the waste, which would limit liquid infiltration and additional leachate generation.

The updated analysis was run using a five-year incremental accumulation of refuse with a single six-inch lift of daily cover soil. A five-year simulation of leachate generation was run and new refuse and daily cover soils were added to the profile. The new layers are modeled with an initial moisture content from the program whereas the existing layer moisture contents are re-initialized using moisture contents from the output of the previous model run. The process continues until the area is inactive when an intermediate cover is placed over the area. Simulations are run through the entire active life of the landfill for each phase until the landfill is assumed to close (assumed to occur after 30 years of operations). A final cover was placed over each of the phases and a final simulation was made for a period of 30 years.

The process of re-initializing the moisture content for the interim cover and five year accumulation of refuse every five years has the effect of attenuating the cyclic high and low spikes of leachate volume recorded for the original model that looked at individual annual leachate generation. Differences in the modeled generation of leachate are also affected by the hydraulic conductivity of the intermediate soil cover layers between cells of refuse. Use of a greater hydraulic conductivity in the 1998 model has the effect of showing faster moisture transport through the refuse prism and into the leachate collection system.

Review the impact of liner system modeled.

The base liner system simulated in the HELP program has almost no impact on calculated leachate volumes captured in the leachate collection and recovery system. The amount of calculated leakage through the uppermost flexible membrane layer of the composite liner system is very small when compared with the volumes assumed to be captured in the leachate collection system. The volume of leakage through the lower of the two double composite liner systems typically calculates to be smaller than the significant digits of the program.

Although a flexible membrane cover is proposed for covering the closed landfill, the HELP program does not allow for a barrier layer to be placed above “infiltration” layers. Therefore, the closed landfill was assumed to be covered with a prescriptive clay cover. Based on our

review of the leachate generation modeling performed, and based on the updated “baseline” leachate generation and parameter sensitivity analysis presented in the attachment to this memorandum, it is our opinion that reasonable values were used and that the results are supportable for the site design.

Review predicted trends in leachate generation rates over time. Why was there an increase in leachate over time in the 60 year model?

The net increase in the modeled amount of leachate in the 60-year (1998) model is a direct effect of the use of a faster hydraulic conductivity for the interim cover soils over refuse. Use of a hydraulic conductivity value greater than measured for on-site soils would allow for greater infiltration resulting in larger volumes of calculated leachate. The 1998 “baseline” model used an assumed hydraulic conductivity value for the intermediate cover soils that resulted in significant moisture migration into the refuse while the landfill was operating. The moisture migrated through the refuse prism during the post closure period gives the impression that the moisture had infiltrated the cover during the post closure period. The updated “baseline” model does not show a pattern of post closure leachate production because of the lower hydraulic conductivity interim cover soils modeled (based on soil data obtained from the site). It is very likely that the late stage leachate production modeled in the 60-year model would be noted in the updated “baseline” model if it was allowed to run for an extended period. In both models, the post closure leachate is likely the result of moisture that entered the refuse prism prior to placement of the final cover system because the moisture penetration through the cover system does not change appreciably in either case. It should be noted that the volume of leachate generated after closure remains relatively low and well within the range of volumes that can be handled by the LCRS. Financial assurance includes costs to handle leachate in the post-closure period, which is to be destroyed by injection into the landfill gas flare system at the site.

Comment No. 3: Review of potential effect of advances in the state of the practice on seismic design (e.g. NGA attenuation models).

Response to Comment No. 3: Based on review of the State of California Fault maps (CGS, 2010) and the California Seismic Hazard Maps (Cao, et. al., 2003), no new geologic data has been released that will significantly alter the seismic hazard analysis performed for the Gregory Canyon Landfill to date. With respect to recent attenuation relationships (specifically the NGA attenuation relationships and others), it is well understood that use of the newer NGA attenuation relationships will result in a lower site acceleration than the older attenuation relationships used to generate the design site acceleration for the Gregory Canyon Landfill (a typical comparison is presented in Figure 1).

Accordingly, it is our opinion that the current seismic hazard analysis used to generate a design site acceleration due to the design earthquake event is appropriate (as well as conservative) for use in seismic design of the Gregory Canyon Landfill.

Comment No. 4: Review of material parameters utilized for the final cover/geomembrane interface used for the slope stability and seismic deformation analyses. Was a seepage condition evaluated?

Response to Comment No. 4: At the time the original cover stability calculations were performed (GLA, 1999), an extensive database of interface shear strength parameters for the textured LLDPE/soil cover interface was not readily available. Accordingly, the initial cover stability analysis was performed assuming the minimum interface shear strength parameters (friction angle of 27 degrees and a zero cohesion value) to achieve a factor of safety of 1.5 for the non-saturated, static case. A fully- or partially-saturated slope (seepage) condition was not originally evaluated for cover stability.

Since then, an extensive database of interface shear strength parameters has been published (GRI, 2005) and is routinely used in slope stability analyses. Average peak interface shear strength properties for a typical textured LLDPE to sandy soil interface yields a friction angle of 26 degrees and a cohesion of 160 psf. Using these average strength parameters, the factor of safety for the static, non-saturated cover condition is 4.1 (Figure 2) and the factor of safety for the static, fully-saturated cover condition is 3.2 (Figure 3).

For the dynamic condition, (assuming a non-saturated cover condition), a yield acceleration of 0.9g is calculated. This yield acceleration (or the horizontal acceleration needed to achieve a factor of safety of 1.0) is greater than twice the calculated horizontal acceleration from the MCE event, accordingly, the anticipated dynamic displacement due to the design earthquake event is negligible.

Comment No. 5: Review of material properties and design configuration utilized in 3-D slope stability analyses.

Response to Comment No. 5: Review of the slope stability calculations indicates that the properties used for the two dimensional slope stability analysis performed in 2003 are similar to the current geotechnical engineering properties used to model earth and geosynthetic materials.

Both a two-dimensional and a three-dimensional slope stability analysis were originally performed for the refuse prism during the initial design process as presented in GLA, 1998. Both analyses produced virtually identical minimum factors of safety for the most critical refuse prism cross section. Since the 1990s, several two-dimensional slope stability programs with more robust failure surface configurations (including non-circular failure surfaces) were placed on the market while the standard of practice of three-dimensional analysis has not changed significantly (the original 3-D software used in the 1998 original analysis is still routinely used today). Accordingly, the initial slope stability analysis from 1998 was subsequently updated by a slope stability program (SLOPE/W) which has a variety of calculation methods and search procedures to determine the critical potential failure surface for a given cross section. The analyses also take advantage of a relatively new slip surface optimization procedure within SLOPE/W, wherein the lowest factor of safety potential slip surface at the end of standard limit

equilibrium iterations is further iterated on a segment-wise basis to find potentially lower factor of safety (and often non-circular) slip surfaces. Use of this procedure will always result in a factor of safety that is as low as or lower than the results after the initial standard limit equilibrium iteration (i.e. it is conservative). Considering the various options available with SLOPE/W as well as the configuration of the landfill (relatively narrow canyon); it is our opinion that the analysis by the use of the two-dimension SLOPE/W software performed in May 2003 (GLA, 2003) supersedes the three-dimensional slope stability analysis previously performed in 1998.

Comment No. 6: Clarification if an evaluation was performed to address the potential for differential settlement between foundation material types.

Response to Comment No. 6: An evaluation was performed addressing the potential for differential settlement between the compacted fill materials (after removal and recompaction of the alluvial materials) and weathered granitic materials at the new landfill subgrade. Considering the relatively gentle site grades and the engineering properties of the residual soils obtained from laboratory testing (Woodward-Clyde, 1995), the anticipated differential settlement between the different foundation materials is expected to be well within the elongation characteristics of the proposed membrane liner materials.

Closing

We trust that the responses contained herein adequately address the issues presented. If you have any additional questions or need additional information, please do not hesitate to contact the undersigned at (858) 451-1136.

Geo-Logic Associates



Joseph G. Franzone, PE, GE
Supervising Geotechnical Engineer



Sarah Battelle, RG CHG
Vice President/Project Manager

Distribution: (1) Addressee-electronic submittal

Attachments References

- Figure 1 – Pre-NGA vs. NGA Site Response Curves
- Figure 2 - Calculation Brief – Non-Saturated Cover Slope Stability
- Figure 3 - Calculation Brief – Saturated Cover Slope Stability
- Leachate Generation Sensitivity Analyses, Proposed Gregory Canyon Landfill

REFERENCES

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- Blake, Thomas. F., 2000b, EQFAULT (Windows 95/98 Version), A Computer Program for the Estimation of Peak Horizontal Acceleration from 3-D Fault Sources."
- Bray, J.D., and E.M. Rathje, 1998, "Earthquake Induced Displacements of Solid Waste Landfills," ASCE Journal of Geotechnical and Geoenvironmental Engineering, vol 124, No. 3, March.
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- California Geological Survey (CGS), 2010, Fault Activity Map of California, Compiled by C.W. Jennings and W.A. Bryant, California Geologic Data Map Series Map No. 8, Scale 1:750,000.
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- Geosynthetic Research Institute (GRI), 2005, Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces by Koerner, GR, and Narejo, D, GRI Report #30, dated June 14, 2005.
- Koerner, 1998, M. K., Designing With Geosynthetics, Prentice Hall,
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- SLOPE/W, 1995, by Geo-Slope International, Inc., Version 3.
- Woodward-Clyde, Geology and Hydrology Report, Gregory Canyon Landfill, Pala, San Diego County, California, Dated March 1995.

ATTACHMENTS

Pre-NGA vs. NGA, Downtown San Francisco, M 7.9, R=14 km, Site Classes B, C, and D

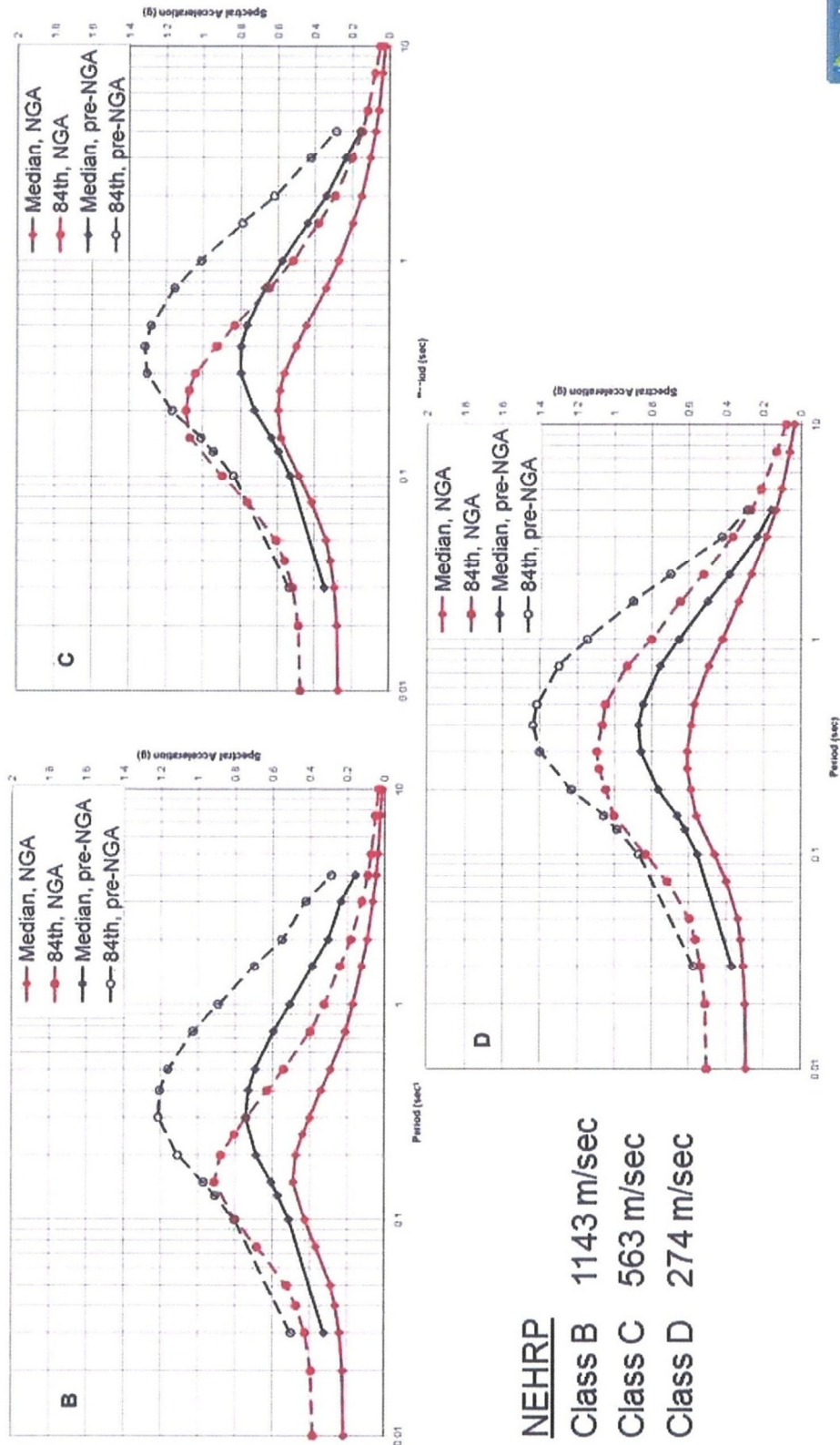


Figure 1 –PreNGA vs. NGA Site Response Curves (Adopted from: EERI Webinar, December 14, 2011: Shear-wave Velocity Profiling and Its Importance to Seismic Design, Jared West, Purdue University, Host)

Calculation Brief

By: JGF Date: 5-23-2012 Subject: Gregory Canyon LF Sheet No. 1 of 1
Chkd. by: _____ Date: _____ Cover Slope Stability Analysis- Infinite Slope PN. 95-039/089

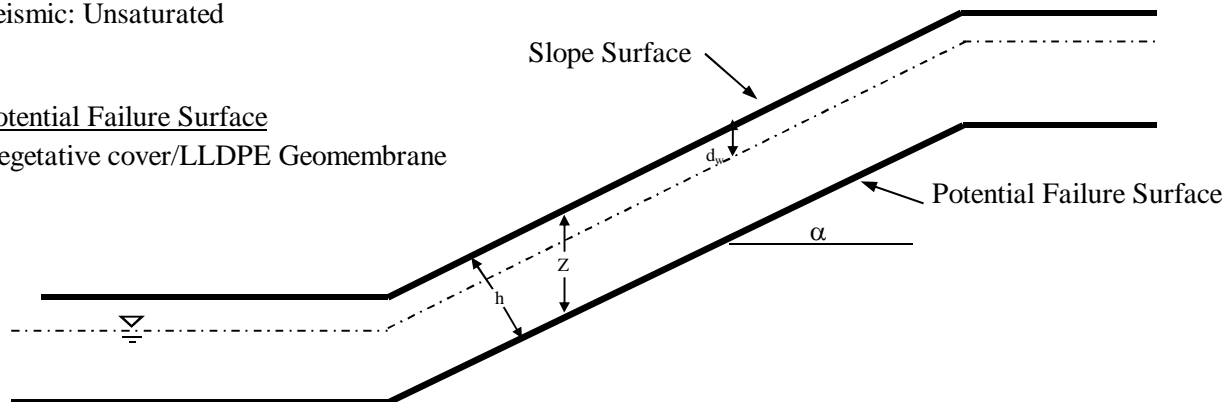
Cover Soil Piezometric Condition

Static: Unsaturated

Seismic: Unsaturated

Potential Failure Surface

Vegetative cover/LLDPE Geomembrane



where:	Final cover thickness:	$h =$	1.9 ft	
	Vertical Cover Thickness:	$Z =$	2 ft	
	Cover Soil Density:	$\gamma =$	100 pcf	
	Interface strength	$c =$	160 psf	} Ref.2
		$\phi =$	26 degrees	
	Slope Angle (3:1, H:V)	$\alpha =$	18.4 degrees	
	Vertical depth to water table (ft)	$d_w =$	2 ft (only for static)	
	Unit weight of water (pcf)	$\gamma_w =$	62.4 pcf	

Under Static conditions, the value of $k_s=0$. Assume 0% saturation for this case (i.e. $d_w=2$).

$$\bullet \text{ Static Factor of Safety }^{(1)} = \frac{c/(\gamma z \cos^2 \alpha) + \tan \phi [1 - (\gamma_w(z - d_w))/(\gamma z)]}{\tan \alpha} = \underline{\underline{4.12}}$$

Under pseudo-static conditions, the yield acceleration = k_s = value of seismic coefficient at FOS = 1.0.

For this case, no water table is present within cover, i.e. $d_w = Z = 2.00$ ft (only for pseudo-static)

$$\bullet \text{ Pseudo-static Factor of Safety }^{**} = \frac{c/(\gamma z \cos^2 \alpha) + \tan \phi [1 - (\gamma_w(z - d_w))/(\gamma z)] - k_s \tan \alpha \tan \phi}{k_s + \tan \alpha}$$

Solve for Factor of Safety = 1.0:

<u>Yield Acceleration = k_s</u>	<u>Pseudo-Static</u>
<u><u>0.90 g</u></u>	<u>Factor of Safety</u>
	<u><u>1.00</u></u>

References: ⁽¹⁾ Matasovic, N., 1991, As referenced in Richardson, G.N., et. Al., 1995, RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, USEPA Publication

(2) GRI, 2005, Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces, Geosynthetic Research Institute, by Koener, GR, and Narejo, D, GRI Report #30, June 14, 2005.

Calculation Brief

By: JGF Date: 5-23-2012 Subject: Gregory Canyon LF Sheet No. 1 of 1
Chkd. by: _____ Date: _____ Cover Slope Stability Analysis- Infinite Slope PN. 95-039/089

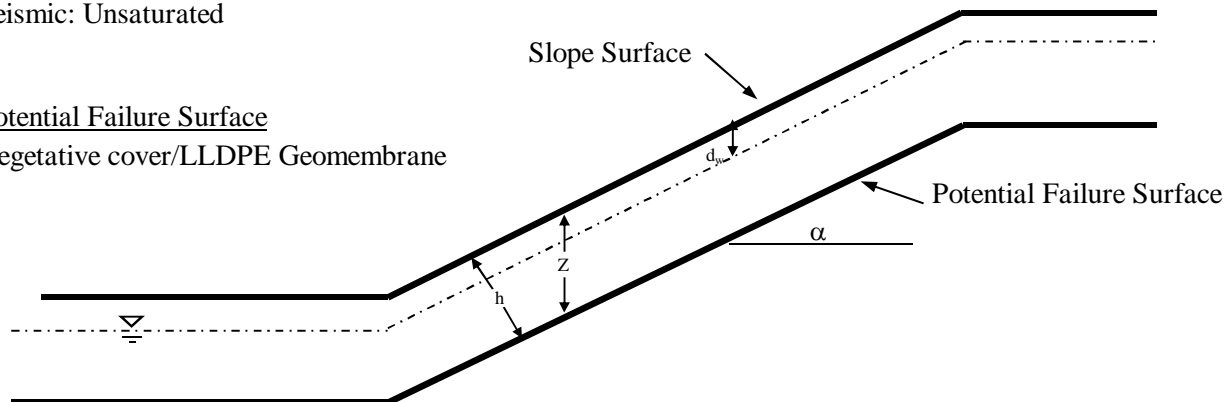
Cover Soil Piezometric Condition

Static: Fully Saturated

Seismic: Unsaturated

Potential Failure Surface

Vegetative cover/LLDPE Geomembrane



where:	Final cover thickness:	h =	1.9 ft	
	Vertical Cover Thickness:	Z =	2 ft	
	Cover Soil Density:	γ =	100 pcf	
	Interface strength	c =	160 psf	} Ref.2
		φ =	26 degrees	
	Slope Angle (3:1, H:V)	α =	18.4 degrees	
	Vertical depth to water table (ft)	d _w =	0 ft (only for static)	
	Unit weight of water (pcf)	γ _w =	62.4 pcf	

Under Static conditions, the value of $k_s=0$. Assume 100% saturation for this case (i.e. $d_w=0$).

$$\bullet \text{ Static Factor of Safety }^{(1)} = \frac{c/(\gamma z \cos^2 \alpha) + \tan \phi [1 - (\gamma_w(z - d_w))/(\gamma z)]}{\tan \alpha} = \underline{\underline{3.21}}$$

Under pseudo-static conditions, the yield acceleration = k_s = value of seismic coefficient at FOS = 1.0.

For this case, no water table is present within cover, i.e. $d_w = Z = 2.00$ ft (only for pseudo-static)

$$\bullet \text{ Pseudo-static Factor of Safety }^{**} = \frac{c/(\gamma z \cos^2 \alpha) + \tan \phi [1 - (\gamma_w(z - d_w))/(\gamma z)] - k_s \tan \alpha \tan \phi}{k_s + \tan \alpha}$$

Solve for Factor of Safety = 1.0:

<u>Yield Acceleration = k_s</u>	<u>Pseudo-Static</u>
<u><u>0.90 g</u></u>	<u>Factor of Safety</u>
	<u><u>1.00</u></u>

References: ⁽¹⁾ Matasovic, N., 1991, As referenced in Richardson, G.N., et. Al., 1995, RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, USEPA Publication

(2) GRI, 2005, Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces, Geosynthetic Research Institute, by Koener, GR, and Narejo, D, GRI Report #30, June 14, 2005.

March 22, 2012
Revised June 29, 2012
Project No. 9539

Gregory Canyon Ltd.
160 Industrial Street, Suite 200
San Marcos, California 92078

Attention: Mr. Jim Simmons

**LEACHATE GENERATION SENSITIVITY ANALYSES
PROPOSED GREGORY CANYON LANDFILL**

INTRODUCTION

This letter report summarizes the results of an updated “baseline” leachate generation analysis and a series of parameter sensitivity analyses completed for the proposed 183-acre Gregory Canyon Landfill (GCLF) in San Diego County, California. This effort was prompted by a review of prior leachate generation analyses by the United States Army Corps of Engineers (USACE) for an Environmental Impact Statement (EIS) being prepared for the GCLF. The USACE Hydrologic Evaluation of Landfill Performance (HELP) computer software and GCLF phasing plans prepared by Bryan A. Stirrat & Associates in 2001 were used for this prior analysis and are based on a simplified (5-year incremental) leachate generation baseline reconstruction of the previously completed leachate generation analyses (GLA, 1998; and addendum GLA, 2001), which had been completed using the most current version of HELP available at that time (version 3.06). The purpose of the current baseline modeling was to employ the most current HELP model software (version 3.07) to support the original model and establish that the original model results used to design the leachate collection and recovery system remain applicable for landfill design purposes. A full leachate generation model (in more detail than the 5-year incremental model runs) was not prepared, and would have been beyond the scope necessary to evaluate the original model.

Modeling of potential leachate generation and accumulated leachate head over the proposed landfill liner was performed using the USACE HELP computer program. Modeling in 1998 and 2001 was performed using version 3.06 of the program; however, version 3.07 was subsequently released, which contains modifications that might result in differences in the volumes of generated leachate under certain conditions. The updated “baseline” leachate generation analysis was performed using more site specific information on cover soil hydraulic conductivity, and reasonable assumptions regarding rainfall and evapotranspiration data. In addition, calibration of the results was completed by comparing the calculated GCLF leachate generation rates to actual observed leachate generation rates obtained from the lined Miramar Landfill, a similar sized landfill, located in a similar region of San Diego County. Comparison of the 1998 model and updated “baseline” model with actual data collected from the Miramar Landfill show similar volumes of leachate generation on a peak annual basis. In addition, the 1998 and updated “baseline” models show over-estimations of monthly leachate production

when compared to data recorded at the Miramar, and Sycamore Landfills (also of similar size and located in San Diego County).

The 1998 leachate generation model remains valid. The existing leachate collection and treatment designs (which were based on the 1998 HELP analyses) are still appropriate and provide ample capacity to contain leachate generated by the facility over the life of the landfill, and through the post-closure period, and are compliant with the regulatory requirement because the maximum leachate head on the liner remains a fraction of the 12-inch maximum standard.

In addition to the “baseline” model, in order to evaluate the effects of a range of parameters, a series of parameter sensitivity analyses were performed. The parameters chosen for these analyses did not represent reasonably expected site conditions, but rather deviated from reasonably expected site conditions in order to assess the affect of variations on the performance of the leachate collection system. The analyses showed that the design of the leachate collection system continued to be appropriate and compliant with the regulatory requirement because the maximum leachate head on the liner remained well below the 12-inch maximum standard even though the parameters fall outside of the expected range of values for the GCLF.

MODEL SETUP

The original and updated “baseline” leachate generation models were set up and run using the methods described by Peyton and Schroeder (1988) to calculate leachate collection drain spacing that would be adequate to maintain head on the liner at levels below the regulatory limit of 12 inches, and to estimate the volume of leachate that might be generated in the landfill over its operating and post-closure life. The program uses landfill design elements, local weather and site specific material parameters to calculate the amount of precipitation that will run off, evaporate, transpire, and infiltrate into the landfill. The program further uses algorithms to calculate the amounts of leachate that will be collected in drains and estimates the thickest accumulation of leachate buildup over the liner membrane.

The following input parameters are specified by the user for landfill design:

- Cover Soil Type
- Cover Slope Gradient
- Leachate Collector Gradient
- Leachate Collector Drain Spacing

The following input parameters are specified by the user for weather:

- Average monthly precipitation
- Latitude
- Solar Radiation
- Average Monthly Temperature

The following input parameters are specified by the user for site specific soil and landfill elements:

- Cover Soil Hydraulic Conductivity
- Estimation of Vegetation Cover

Model input parameters were similar to those used in the earlier model, but were adjusted based on the current standards of practice and calibrated to actual leachate generation data obtained from the Miramar and Sycamore Landfills in San Diego.

Climate

As in the previous leachate generation model (GLA, 1998), initial climate properties were selected from a table of default values included in the HELP v.3.07 software for the City of San Diego and corrected for the latitude of the proposed GCLF.

Precipitation data were synthetically generated from the HELP program using algorithms for San Diego that mimic a pattern of the wettest five years on record scaled to an annual average of 18.64 inches based on isohyetal maps of the area. The HELP program was then used to synthesize a 30-year variable time history based on typical weather patterns for the San Diego area. The slight difference in average annual precipitation values from those generated by the original model runs result from generating the data using a 30-year cycle for the revised analysis and a 60-year cycle for the original analysis.

The long term average annual precipitation number is used to generate the 30-year time history for the HELP analyses. It is based on a cycle of high and low precipitation events typical for the San Diego area so precipitation events are clustered in the winter months typical of weather patterns in southern California.

Material properties

The following engineering and hydraulic properties of materials were determined from HELP3.07 default values, site-specific data where it was available and/or calibration of the model results to the actual leachate generation data reported for the Miramar Landfill.

Layer	USCS	Thickness (inches)	Porosity	Saturated hydraulic conductivity (cm/s)
Vegetative cover	SM	24	0.473	1.25E-05
Foundation and operations soil layers	SM	24	0.473	1.25E-05
Interim soil cover	SM	12	0.473	1.25E-05
Daily soil cover	SM	6	0.473	1.25E-05
Refuse	--	Variable	0.671	1.00E-03
Operations layer	SM	24	0.473	5.2E-04
LCRS layer	GP	12	0.397	3.00E-02
60 mil HDPE	--	0.06	--	2.00E-13
Low permeability layer	CH	24	0.400	1.00E-07

Note: The order in the table does not represent the order in the different model scenarios.

The geometric mean of hydraulic conductivity values obtained from on-site soil samples collected by Woodward-Clyde Consultants (1995) was calculated to be 4.27E-06 cm/sec. A more conservative (greater permeability) value of 1.25E-05 cm/sec was used for the soil cover

materials based on calibration to measured leachate volumes at the Miramar Landfill. The faster hydraulic conductivity value (approximately a three-fold increase in the hydraulic conductivity) calibrates well with the Miramar Landfill despite the fact that the interim cover soils at the Miramar Landfill contain fewer fines than soils in the borrow source at Gregory Canyon. This is a typical result for the HELP software because the algorithms typically overestimate leachate production. The developers of the HELP program (Peyton and Schroeder, 1988) found that leachate production volumes were overestimated by approximately 35% compared with actual data at one landfill that they studied. This is most likely the result of the field capacity concept in the HELP program that precludes capillary moisture suction from depths below the assigned evaporative zone depth, which has the net effect of overestimating deep percolation and results in the overestimation of leachate production (Stevens and Coons, 1994)

The bottom liner was assumed to be constructed to excellent installation quality as defined and determined appropriate in the HELP model instructional manual as one pinhole leak and one installation defect per acre (10 percent defects per acre). This installation quality is consistent with the proposed construction quality assurance (CQA) program proposed for the site, which will include third party CQA with leak detection following placement of the landfill liner materials and operations layer. The evaporative zone depth was assumed to be equal to the median value of 32 inches recommended by the HELP program for San Diego. In addition, a leaf area index of 1 was used to represent a poor stand of grass development on the landfill. This was considered reasonable because the landfill operations will include placement of interim cover and re-vegetation of areas of the landfill that will be inactive for more than 180 days resulting in a much higher grass density to minimize soil erosion.

Model configuration

In general, the design plans call for development of the landfill from north to south, and from west to east. Modeling of the 30-year active life of the landfill, as well as the 30-year post-closure period was performed by subdividing the 183-acre landfill into six phases. As a baseline model, each active incremental model run represents an average five year accumulation of refuse placed at the beginning of each period. Annual and daily leachate production volumes are calculated by the HELP program for the cumulative thickness over a five year run cycle. The following table summarizes these modeled phases.

Phase	Floor Area (acres)	Slope Area (acres)	Total Acres per Phase
1A	31.4	4.3	35.7
1B	4.4	6.4	10.9
2	12.8	16.4	29.2
3A	12.2	20.1	32.3
3B	31.6	20.6	52.2
4	1.0	21.6	22.6
Total	93.5	89.4	182.9

In addition to the general phasing of the GCLF, leachate was assumed to have a maximum travel distance of 500 feet in high permeability gravel before encountering a floor LCRS drain, or 100 feet in interim cover soils before encountering a bench LCRS drain. HELP3.07 assumes all drains are 100% efficient.

Finally, although a flexible membrane cover system is proposed, membranes are not readily accommodated in the HELP model and as a result, closure of the proposed Gregory Canyon Landfill was conservatively modeled using a 24-inch foundation layer, a 12-inch low permeability soil layer, and an upper 24-inch topsoil/vegetative layer.

Model profiles

The bottom profile of the modeled cells differed depending on whether they were floor or back slope cells. The following table summarizes the model profiles:

Cell type	Layers (from top to bottom)	Thickness (inches)	Slope	Maximum distance to drain
Floor	Daily/Interim/Final Cover Refuse Operations layer LCRS gravel 60 mil HDPE Low Permeability Layer	6/12/42 Variable 24 12 0.06 24	3%	500 feet
Back slopes	Refuse Ops./Drainage Layer 60 mil HDPE Low Permeability Layer	Variable 24 0.06 24	50%	100 feet

Note: Because geotextiles do not affect leachate hydrology significantly, they are not included in the model.

Precipitation Runoff Potential

The HELP program uses an algorithm to determine precipitation runoff potential based on cover slope gradient, soil type, length of travel of water flow, and amount of vegetation cover. The program selects a curve number from a digital library to perform infiltration calculations based on the above mentioned parameters. The analyses performed for the 1998, "baseline" model, and sensitivity analyses assume a cover gradient of 29% and a runoff length of 300 feet.

Vegetation Cover

The amount of vegetation established on the cover is a dimensionless number that corresponds to the ratio of the leaf area of the plants to the area of the ground surface. The model calculates infiltration against the effects of plant transpiration using a parameter called the Leaf Area Index (LAI) which is defined as follows:

Leaf Area Index	Definition	Model Usage
0	Bare Ground	Not Used
1	Poorly Established Grass	Active and Intermediate Phases
2	Fairly Established Grass	Post Closure Period
3.5	Well Established Grass	Not Used
5	Well Established Grass, Shrubs, and Trees	Not Used

The use of a LAI of 1 for the unclosed portions of the landfill is warranted because hydro-seeding and erosion control measures will be implemented on any portion of the landfill not expected to receive waste within 180 days and because grass seed usually germinates shortly after the start of the rainy season in southern California. Given the ease of establishing grass cover, this LAI is considered reasonable.

Evaporation Potential

Precipitation that does not run off the landfill will infiltrate into the soil profile. That water may migrate through the cover or be pulled out of the soil column via evaporation and/or plant transpiration. Evaporation is strongly influenced by soil type, temperature, solar radiation, and vegetative cover characteristics. The depth to which evaporation of water can occur can greatly exceed the depth to which plant roots extend and can occur even if there is no vegetation at all. The GCLF leachate generation models assume that the Evaporative Zone Depth is 32 inches for active, intermediate, and closed landfill conditions. This is consistent with the average values for the San Diego area cited in the HELP program manual and is consistent with clayey and silty soils that will be used at the GCLF for daily and intermediate soil cover.

Baseline Model Results

Using the climatic and material values described above, the HELP v.3.07 analysis was performed iteratively for a simulated 30-year operations period and a 30-year post-closure period. Results are summarized in the electronic files that accompany this report. Average leachate generation predicted by the updated model is summarized in Table 1. In the updated model, a peak annual leachate generation of 414,000 gallons occurs with a peak daily leachate volume of 5,700 gallons. By way of comparison, the original (GLA, 1998) leachate generation model resulted in a peak annual volume of approximately 400,000 gallons and a peak daily volume of 9,245 gallons. Once the landfill has been in operation for more than 20 years, the model shows that although the moisture content increases over time, the accumulated moisture does not exceed the field capacity within the refuse and as a result very little leachate is actually generated by the model.

The pattern of abundant leachate production during the early stages of landfill development followed by lesser quantities during later stages is quite common in the southwestern United States. Leachate production at landfills is typically very high when refuse prisms are thinnest. Leachate production for older landfills with thick refuse prisms typically approach zero because the thicker lifts of refuse attenuate the episodic slugs of leachate produced by individual storm events. This occurs because the default initial moisture content of refuse specified by the HELP model is less than the field capacity (a result of the large amounts of dry paper products in the waste stream). Research conducted in support of the Environmental Protection Agency's approved program in New Mexico support using initial moisture contents for municipal Class III refuse that are lower than default initial moisture contents in the HELP model (Stevens and Coons, 1994). Even for semiarid sites in New Mexico with similar rainfall totals to Gregory Canyon, the state requires a demonstration that leachate volumes will fall to zero during the post closure period.

Based on our experience, although not predicted by the model, there are instances at other landfills of continued leachate generation during later operational years and following closure. If this were to occur at GCLF, there is ample capacity to collect and store the leachate that could be generated within the existing design.

The above baseline analysis compares well with the actual leachate volumes generated from the Miramar and Sycamore Landfills, which are also located in San Diego County. The Miramar Landfill is of a similar size to the GCLF (a 180-acre active landfill) in a similar San Diego climate, where the average daily leachate generation was about 3,000 gallons per day in 2010; a high rainfall year. Peak leachate was recorded during January 2010 when 130,500 gallons of leachate was generated for that entire month, an average of about 4,200 gallons per day. At the existing 150-acre Sycamore Landfill, average leachate generation of 73 gallons per month per acre is reported (City of San Diego Sycamore Landfill Master Development Plan, 2012), or 13,359 gallons per month (445 gallons per day) for an equivalent 183-acre landfill.

Calculated peak daily head on the liner reaches a maximum of 1.7-inches (during year three), well within the 12-inch range allowed by regulations (e.g., Section 258.40 of Subpart D of Title 40 of the Code of Federal Regulations).

Based on the modeling results, it is concluded that the updated baseline leachate generation analyses are consistent with the previous model results, are consistent with the actual leachate capture volumes measured at the Miramar Landfill and Sycamore Landfill, and satisfy the requirements of current state and federal regulations.

Parameter Sensitivity Analyses

An analysis of parameter sensitivity was performed solely for the purpose of evaluating the effects of a range of parameters in the HELP model. The use of different parameter values do not represent realistic or reasonably expected site conditions, but are meant to test the model. The analysis was performed by using a standardized landfill profile and varying the non-standardized or estimated program parameters such as evaporative zone depth, leaf area index, cover soil hydraulic conductivity, and cover runoff length. Each variation or sensitivity analysis was run using version 3.06 and version 3.07 to determine the relative change in calculated leachate volume generated. The volumes calculated as part of the sensitivity analyses are based on a five year period with variable rainfall and a one acre area. These parameters were varied over a range of typical values to calculate the magnitude of the model's response (Table 2). However, these values are extreme conditions that are not representative of actual leachate that would be generated at the GCLF.

An example of how values were selected for the leachate production modeling is the evaporative zone depth. The evaporative zone depth used for the 1998 leachate production modeling (32 inches) was selected as an appropriate value for the latitude, temperature, and precipitation at the GCLF. An evaporative zone depth of 16 inches is more appropriate for an environment with significantly less solar radiation, lower temperatures, and more precipitation and, conversely, an evaporative zone depth of 48 inches is more appropriate for an environment with considerably more solar radiation, higher temperatures, and less precipitation. Although the evaporative zone depth for the sensitivity analyses was varied from 16 to 48-inches, it was done for purposes of demonstrating model response and not because it is considered site-appropriate. Use of the minimum evaporative zone depth (16 inches) results in over-estimation of leachate volumes, and use of the maximum evaporative zone depth (48 inches) results in an underestimation of leachate volumes for the site, when compared with actual measured values from the Miramar and Sycamore Landfills.

As shown on Table 2, analysis of the “baseline” model (using the parameters from the updated model and HELP version 3.07) result in higher volumes of leachate generated compared to the volume calculated using version 3.06. Similarly, use of version 3.07 typically results in higher calculated volumes of leachate compared to version 3.06 for most sensitivity analyses. Table 2 presents the changes in calculated leachate volume generated for different sensitivity parameters. It clearly shows that the HELP program version 3.07 has a conservative bias compared to version 3.06, meaning that the calculated volumes of leachate are either the same or higher.

Of the model parameters tested, runoff length was the least sensitive parameter with changes in the calculated volume of leachate changing by about 5% in version 3.07 with a runoff length varying from 100 feet to 1,000 feet. This parameter has limited bearing on calculated leachate volumes because the amount of infiltration is limited by the hydraulic conductivity of the cover soils.

Changes in the LAI have a slightly greater impact on the calculated volumes of leachate generated with a maximum change of 46% using version 3.07 and only 23% when using version 3.06. The inverse relationship of a higher LAI resulting in greater leachate generation is observed between the LAI of 0 and 1 for the model developed using HELP version 3.07. This is most likely caused by a function in the software that increases the hydraulic conductivity in the root zone, which is a condition that can occur as the plants grow and disturb the original soil fabric. The calculated amount of leachate decreases when the LAI is increased to 2 because plant transpiration exceeds the increased infiltration caused by the disturbance of the plant roots.

The evaporative zone depth is sensitive to changes over the range of values recommended by the HELP program supporting documentation. Based on the isohyetal maps in the HELP software manual, an evaporative zone depth of 32 to 48 inches is considered reasonable for the GCLF site; values less than 32 inches are not considered reasonable for the climatic conditions at the GCLF, but are considered more appropriate for places with lower average temperatures and located at higher latitudes. A value of 16 inches results in over-calculated volumes of leachate production when compared with the Miramar and Sycamore landfill data, though the calculated leachate head on liner (1.21 inches) is still well below the maximum standard of 12-inches. Increasing the evaporative zone depth to 48 inches results in an under-calculation of generated leachate volumes, but the difference is less striking than with 16 inches.

The hydraulic conductivity of the cover soil is by far the most sensitive parameter to incremental changes. In this instance, there is a substantial amount of existing on-site data, and the value chosen for the “baseline” model was approximately three times faster than the calculated geometric mean of hydraulic conductivity values measured on site soil samples, and thus considered to be conservative. The values selected for the sensitivity analyses were chosen to represent a reasonable range above and below the value used for the “baseline” model. Varying hydraulic conductivity values results in leachate volumes that are inconsistent with actual leachate volume data from Miramar and Sycamore Landfills. The incremental differences in leachate volumes calculated using version 3.06 are smaller than the differences calculated using version 3.07 with both yielding greater volumes when the hydraulic conductivity is increased (faster).

CONCLUSIONS

The parameters selected for use in the baseline modeling of leachate production at the GCLF with the HELP program are considered reasonable and the calculated volumes compare favorably with actual measured volumes from the Miramar Landfill, an active 180-acre landfill within San Diego County, and well above average volumes measured at the active 150-acre Sycamore Landfill, also located within San Diego County. Varying model input parameters in a test of model sensitivity can result in over- or under-estimations of leachate production when parameters are outside of the range of reasonable values. On the basis of the results of the baseline analysis, it is concluded that the existing leachate collection and treatment designs (which were based on the 1998 HELP analyses) are still appropriate and provide ample capacity to contain leachate generated by the facility over the life of the landfill and through the post-closure period.

Although the original 1998 modeling suggested some leachate would be generated during the post closure period, the lack of leachate generation in later years of landfill development and in the post-closure period identified in this revised model compares favorably with modeling performed for other semiarid sites throughout the pacific coast and southwest (Stevens and Coons, 1994). Although there are dissimilar patterns of leachate production from one model to the other, the differences can be explained by the changes in applied cover soil hydraulic conductivity. Both models calculate leachate volumes that are similar and are backed up by measured volumes from landfills constructed in similar environments. The leachate collection system would have adequate capacity to manage the leachate in either event. In addition, financial assurance mechanisms are in place to continue to address the collection and disposal of leachate should it be generated during the post-closure period. The “baseline” model and sensitivity model indicate compliance with the regulatory requirement because the maximum leachate head on the liner is much less than, and does not come close to the 12-inch maximum standard.

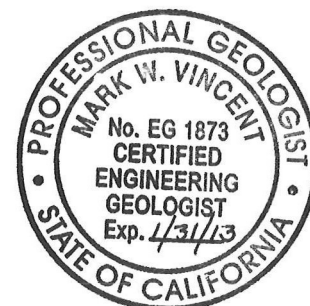
CLOSURE

This report is based on our interpretation of the modeling data described above. Our firm should be notified of any pertinent change in the project or if conditions are found to differ from those described herein, since this may require reevaluation of our conclusions. This report has not been prepared for use by parties or projects other than those named or described above. It may not contain sufficient information for other parties or other purposes. It has been prepared in accordance with generally accepted geotechnical practices and makes no other warranties, either express or implied, as to the professional advice or data included in it.

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Attachments: Table 1 – Updated HELP Model Analysis
Table 2 – Comparison of Parameter Sensitivity

REFERENCES

- Geo-Logic Associates, 1998, Leachate Generation Analysis, Proposed Gregory Canyon Landfill, December 18, 1998.
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- Peyton, R.L., Schroeder, P.R., 1988, Field verification of HELP model for landfills: Journal of Environmental Engineering, American Society of Civil Engineers, v. 114, no. 2, p.247-269.
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TABLE 1
Updated HELP Model Analysis
Gregory Canyon Landfill
San Diego County, California

Analyses performed using HELP version 3.07.

Year	Total Annual Leachate (cu. ft.)	Total Annual Leachate (gallons)	Peak Daily Leachate (cu. ft.)	Peak Daily Leachate (gallons)	Peak Head on Liner	
					Slope (inches)	Floor (inches)
1	16,310	122,015	641	4,795	1.7	1.5
2	20,374	152,421				
3	51,812	387,604				
4	37,227	278,494				
5	24,410	182,613				
6	55,320	413,849	760	5,688	0.03	1.24
7	255	1,908				
8	88	655				
9	36	266				
10	58	437				
11	158	1,181	4	33	0.05	0.02
12	57	424				
13	91	682				
14	129	967				
15	101	752				
16	2,601	19,457	64	482	0.02	0.1
17	441	3,299				
18	84	627				
19	52	391				
20	21	156				
21	26	192	43	325	0.12	0.01
22	1,016	7,602				
23	23	169				
24	248	1,856				
25	136	1,018				
26	0	0	0	0	0	0
27	0	0				
28	0	0				
29	0	0				
30	0	0				
31-60	0	0	0	0	0	0

Table 2
Comparison of Parameter Sensitivity
Gregory Canyon Landfill
San Diego County, California

Model	Leaf Area Index	Evaporative Zone Index (inches)	Run Off Length (feet)	Cover Soil Hydraulic Conductivity (cm/sec)	5 Year Average Annual Leachate Volume (cu. ft.)*	5 Year Average Annual Leachate Volume (gallons)*	Peak Leachate Head Over Liner (inches)	Peak Daily Leachate Volume (cu. ft.)*	Peak Daily Leachate Volume (gallons)*
3.06	2	32	300	1.25E-05	413	3090	0.08	1.49	11
3.06	1	32	300	1.25E-05	491	3673	0.11	1.94	15
3.06	0	32	300	1.25E-05	606	4533	0.11	2.15	16
3.06	1	16	300	1.25E-05	1225	9164	0.59	11.05	83
3.06	1	32	300	1.25E-05	491	3673	0.11	1.94	15
3.06	1	48	300	1.25E-05	640	4788	0.16	2.99	22
3.06	1	32	100	1.25E-05	487	3643	0.10	1.89	14
3.06	1	32	300	1.25E-05	491	3673	0.11	1.94	15
3.06	1	32	1000	1.25E-05	479	3583	0.10	1.83	14
3.06	1	32	300	1.50E-05	488	3651	0.10	1.84	14
3.06	1	32	300	1.25E-05	491	3673	0.11	1.94	15
3.06	1	32	300	1.00E-05	516	3860	0.11	2.06	15
3.07	2	32	300	1.25E-05	413	3090	0.08	1.51	11
3.07	1	32	300	1.25E-05	729	5454	0.19	3.63	27
3.07	0	32	300	1.25E-05	606	4533	0.11	2.15	16
3.07	1	16	300	1.25E-05	2037	15239	1.21	22.96	172
3.07	1	32	300	1.25E-05	729	5454	0.19	3.63	27
3.07	1	48	300	1.25E-05	640	4788	0.16	2.99	22
3.07	1	32	100	1.25E-05	741	5543	0.21	3.86	29
3.07	1	32	300	1.25E-05	729	5454	0.19	3.63	27
3.07	1	32	1000	1.25E-05	709	5304	0.19	3.61	27
3.07	1	32	300	1.50E-05	1321	9882	0.75	14.21	106
3.07	1	32	300	1.25E-05	729	5454	0.19	3.63	27
3.07	1	32	300	1.00E-05	516	3860	0.11	2.05	15

*Note: Results show leachate volumes generated on a per acre basis for models created to test parameter sensitivity only. They do not necessarily reflect real-world expected leachate volumes.

Value adjusted for sensitivity analysis

Calculated values are higher because program increases hydraulic conductivity from plant roots.

